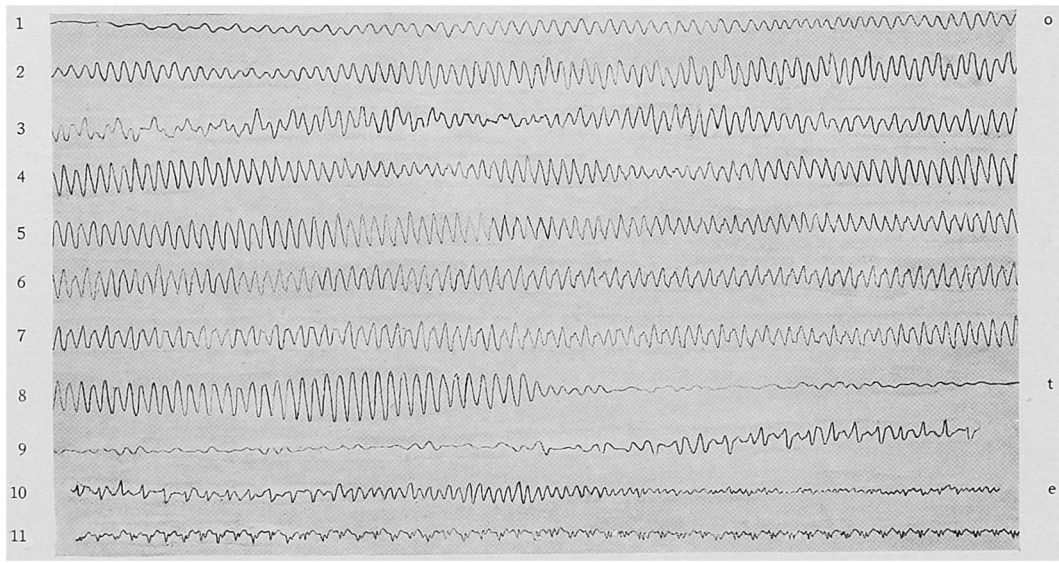


PLATE I

Begins with vowel ''O'' of ''O teco'' etc. This continues to the eighth line, where the singer begins to prepare for the high C, which begins about the middle of the ninth line

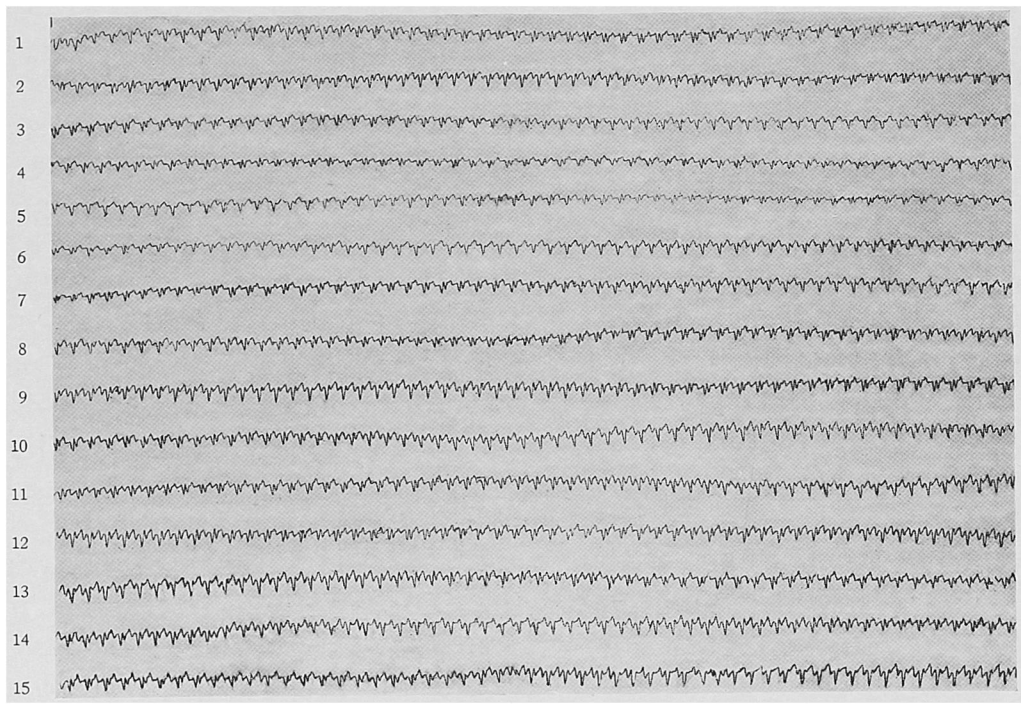
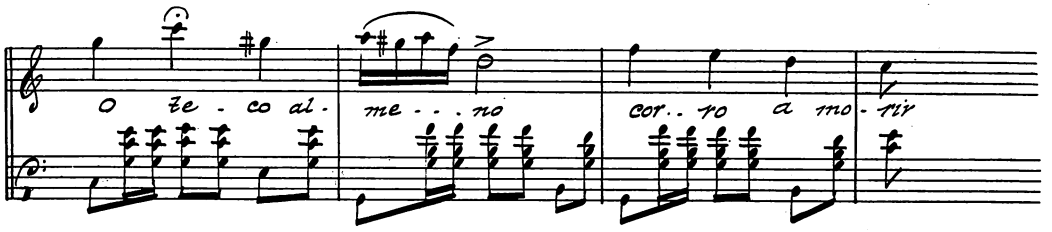


PLATE II

This entire plate shows the continuation of the high C

WHEN CARUSO SINGS HIGH "C"



From *Di quella pira*, "Trovatore"

THE eight plates which illustrate this article, form a photographic record, made by a method too complicated to be explained here, of the vibrations of Caruso's voice, when that distinguished tenor sings "o teco almeno corro a morir" in "Trovatore." It is on the vowel "e" in "teco" that occurs the high "c," a note not written by Verdi, but introduced and, when introduced, quickly established at this point in the opera, as a test of a robust, high tenor voice. In point of fact, however, since it has become necessary for tenors to sing the high "c" in "Trovatore," or eschew the opera entirely, the number is often transposed, so that the singer can deliver an alleged "high 'c'" on b-flat, which is only half a tone higher than "a," the usual boundary note of the upper range of the tenor; all of which is not only interesting, but true. When the Caruso record was made, however, the tenor sang high "c."

The original records are on sheets that measure about 12 by 8 inches and on which the sequence of the vibrations are shown in a series, which must be imagined as pasted together and unrolled from a reel. Were this done, it would be found that Caruso's high "c" was held so long that, were the strips recording it pasted together, they would measure fifty-eight feet. While one cannot say that Caruso's high "c" in "Trovatore" is fifty-eight feet long, the fact that its record required that length of strip proves that it was superbly placed and held.

This fascinating record was made by Dr. E. W. Scripture, for Dr. Frank E. Miller, the distinguished throat, nose and ear specialist and noted as a profound student of the physiology and psychology of voice production, whose discoveries are beginning to bring order out of the chaos that hitherto has existed in voice training. The explanation of the plates and the notes that follow are supplied by Dr. Miller as the result of a conference between himself, Dr. Scripture and others.

Plate I—This plate begins with a record of the vowel "o" as the singer begins with "o-teco-almeno," etc. The vibrations are seen to be arranged in groups of two. Each group corresponds to one vibration of the singer's larynx; such a group of vibrations will be termed a "vowel wave." The vowel waves at the start are very faint; they

gradually increase in loudness. This is a record of the gentle beginning which is found in most of Caruso's initial vowels. The vowel "o" lasts through the middle of the eighth line. The height of the waves rises and falls indicating that the vowel is sometimes louder and sometimes weaker. It swells to the maximum height just before it closes, showing that Caruso ends the vowel loudly and snappily. This is characteristic of most of his vowels, as shown in the following plates.

The form of the vowel wave, *i. e.*, its completion out of minor vibrations, changes steadily. This indicates that the sound of the vowel varies. The waves in line six, for example, show different vibrations from the waves in line one. On the other hand, certain similarity of the waves throughout the whole vowel exists. It is noticed that at nearly all points the wave group consists of one large vibration and another a trifle smaller; this indicates the presence of the overtone produced by resonance, an essential in voice-production known to every advanced student in vocal art-science, nearly but not quite an octave above the tone of the larynx. The record thus shows that the vowel has the sound throughout, but that its character changes from time to time.

Following the "o" there should be a record of the sound "t." For this sound the record should be an absolutely straight line, because the larynx does not vibrate during "t." It shows, however, fairly strong vibrations from the middle of the eighth line to nearly the middle of the ninth. These prove not only that the larynx vibrated during this time, but also that the tongue was not tightly closed for the "t." The "t" with vibrations of the larynx is termed a sonant "t," resembling rather a "d;" and a "t" with a loose closure is termed a fricative "t," resembling a "th." Thus the sound at this place was not on a true "t," but a sonant fricative "t" resembling the "th" in "there."

The reason for the substitution of this sound for a true "t" is obvious. The larynx vibrates during the preceding vowel and during the following one. Moreover, the singer is getting ready for a supreme effort in the following vowel on high "*c*." It would be a more difficult adjustment to interrupt the laryngeal vibrations for a moment to make the "t." It is much easier to let the larynx continue to vibrate during this short time, just as it is easier to slow down a car for a moment than to suddenly stop it and start it again.

The vowel waves beginning in the ninth line of Plate I become shorter and shorter. The length of the vowel wave registers the pitch of the tone from the larynx. The voice thus rises rather rapidly to the high "*c*," on which the tone is sung.

Plate II—This continues the record of the vowel "e" on high "*c*," from Plate I. The vowel wave is very constant in form, indicating that the vocal quality remained unchanged. It varies slightly in length, undergoing some slight fluctuations in pitch. The high "*c*" was continued for a long time, the record occupying over fifty feet of the strips of paper on which it was obtained.

Plates III and *IV*—Of these two plates, the former continues another portion of the vowel "e" on the high "*c*;" while Plate IV shows the close of the vowel on high "*c*." The vowel is

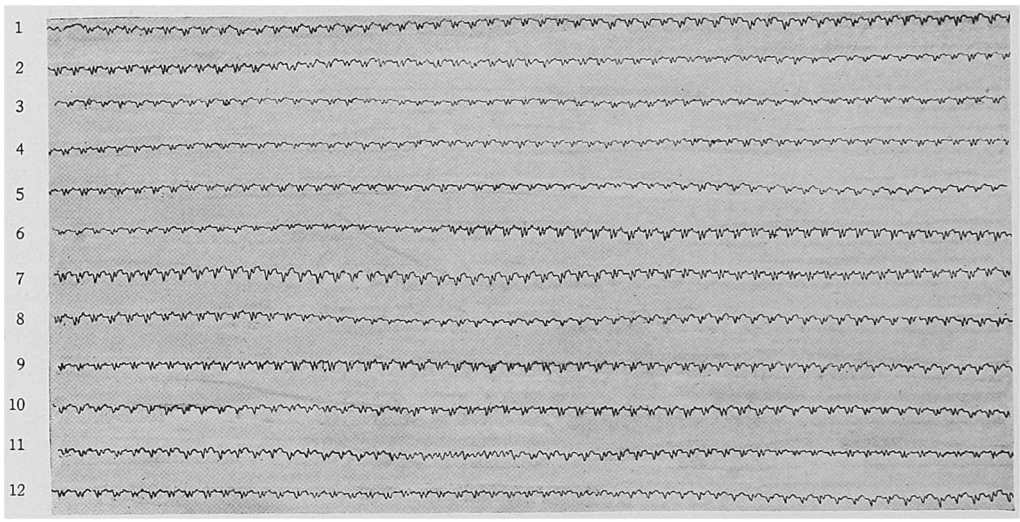


PLATE III

The high C continues throughout this entire plate

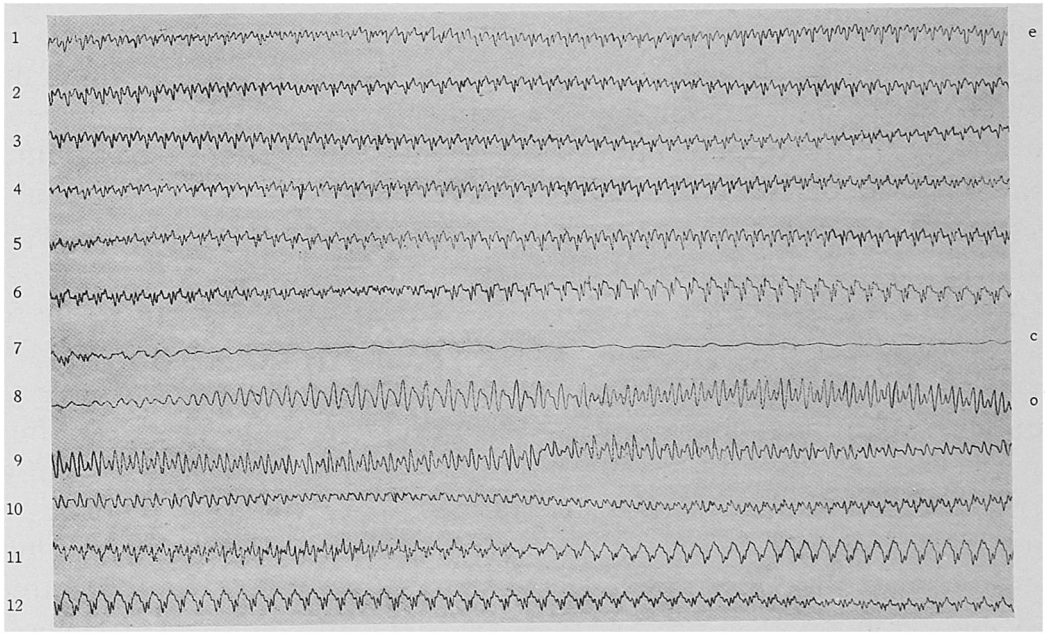


PLATE IV

The first six lines continue and end the high C. The remaining lines show the syllable "co" of "te-co"

followed by the consonant "c" which is the sound of "k." The record here should be an absolutely straight line because the larynx does not vibrate during "k." Yet the vibrations recorded here show that the larynx did vibrate. The sound was thus a sonant "k" made so doubtless for reasons similar to those that influence the vibrations on "t."

The vowel "o" occupies the next two and a half lines. At the start it shows considerable resemblance to parts of the vowel "o" of Plate I. The wave character rapidly changes, however, showing that the "o" sound is altering in character. The change becomes greater until we have the typical vowel wave for "ā" (pronounced "ah") in the latter part of line ten.

Plate V—This begins with the vowel "a" of the word "almeno." With the end of the second line the vowel waves change to those for "l." These in turn change for "m." Both of these are faint, short sounds. the vowel "e" starts in with almost full intensity. Its waves for awhile resemble those of "e" in "teco." Beginning with the end of the sixth line and extending to the end of the eighth, a curious deformity of the vowel waves is noticed. They no longer have the regularity of the ordinary vowel. They rise and fall and have their shapes modified, just as though some longer vibrations were interfering. The other vibration has a length that varies with the first part of the vowel "o."

Plate VI—The first four lines of this plate contain the latter portion of the vowel "o" of "almeno." The following lines are records of the accompaniment.

The latter portion of line eight shows vowel waves which continue through a large part of line nine. There are too few of them to be the record of even a short vowel in song. By studying backward from the close of the plate we can determine what they are. The last two and a quarter lines of the plate are a record of the first vowel "o" in the word "corro." This must be preceded by a record of "c" which is pronounced like "k" just as in Plate III. This "k" is sonant instead of silent. The waves in lines eight and nine are, therefore, a record of the short sound which preceded the "k." Carefully listening to the disc enables the ear to detect a minute vowel produced before the "k."

Plate VII—The first two lines of this plate give the last part of the vowel "o." It has the loud, snappy ending noticed in Plate I. The next line gives a record of the rolled "r." The fourth and eighth lines give a record of the final vowel "o" of "corro" with the vowel "a" of "amorir." These two vowels are united into a diphthong. This diphthong also has the strong, snappy ending already referred to. The vibrations of the "m" are seen in this line. The last two lines show the vowel "o."

Plate VIII—The first two and a half lines of this plate belong to the vowel "o." The "r" appears as a singular interruption in the middle of the third line. The vowel "i" extends through the fifth line. The next line records the final "r."

Notes on Voice Waves

The voice consists of the tone from the glottis modified by resonating cavities above and below it.

This tone, "the laryngeal tone," is produced by the closure of the vocal

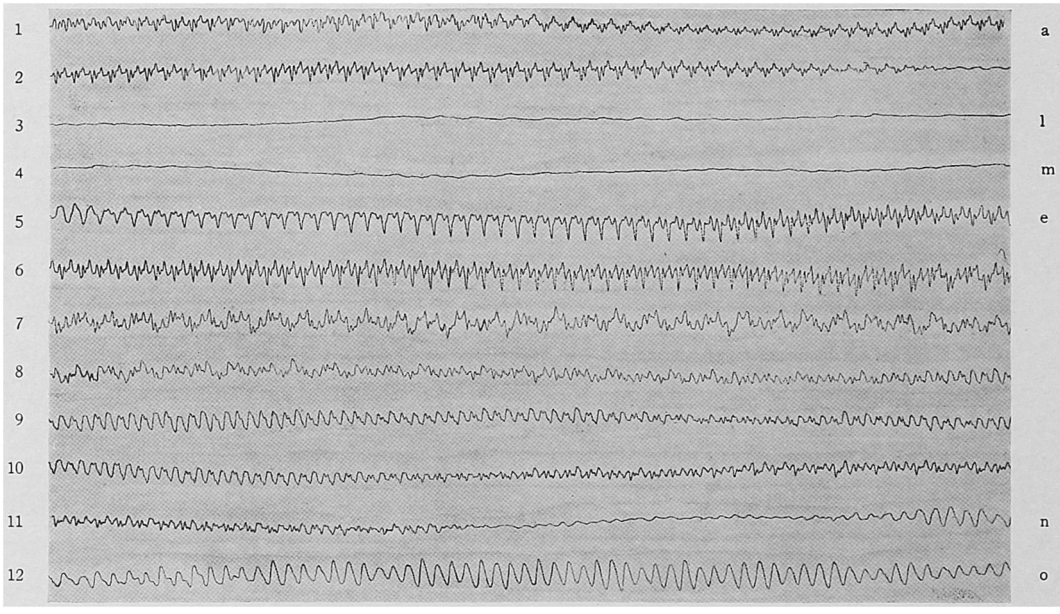


PLATE V

This plate registers the word ''almeno''

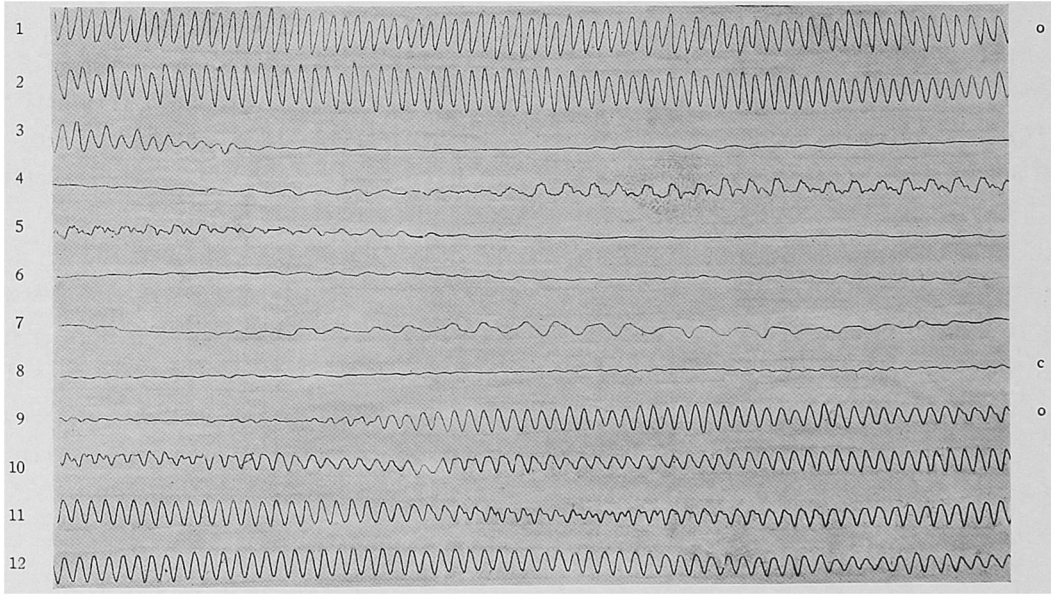


PLATE VI

The first nine lines give the vowel ''o'' of ''o corro.'' The remaining lines give the ''co'' of ''corro''

lips across an air passage from the lungs. The vocal lips are composed of two muscles, namely, the thyreo-arytenoid (externus) and the vocali (usually called the vocal cords). The muscles on each side form a triangular mass of flesh which in no way bears any resemblance to a cord or membrane. It cannot possibly vibrate like a cord or membrane. It vibrates by compression, yielding sidewise to omit puffs of air. This has been directly observed by Musold and Rothi with the laryngostroboscope. It has been observed constantly with the powerful laryngostroboscope which Dr. Frank E. Miller has devised, and has demonstrated to a large number of persons at the New York Academy of Medicine.

The glottis vibrating in this way omits a series of puffs of air of the same nature as those emitted by a tube opened and shut rapidly, as in the case of the well known instrument, the "siren," which is a disc with a number of holes rotating in a tube. These puffs of air are of the nature of a sudden compression with succeeding vibrations of lessening strength. The musical character of a singer's laryngeal tone depends upon the form of these vibrations. These forms depend in turn upon the manner in which the vocal lips vibrate. In a voice where there is a good musical quality these vibrations have a form that impresses the ear pleasantly. Every change in the vocal muscle or the thyreo-arytenoid muscle will produce a difference in the form of the puff and consequently in the musical quality. Since the muscles of the vocal lips are a part of the musical apparatus of the larynx, their activity and adjustment will depend not only on the way in which they themselves are innervated, but also on the adjustment of the surrounding intrinsic or extrinsic muscles of the larynx.

The character of the vibrations from the larynx is modified by the complicated resonance cavities of the pharynx, mouth, and nose, and by chest cavity. The modification occurs according to the law governing the action of resonating cavities with soft and semi-soft walls.

The resulting tone, as it issues from the mouth, consists of vibrations produced in the way just described. On the phonograph or the gramophone it can be studied by the careful methods devised by Professor Hermann and Dr. Miller.

A series of such curves of the voice of Caruso is presented above.

When such a curve of the voice lies before us, we can do several things. In the first place we can analyze it into a series of curves with the wave lengths in the relation 1, 2, 3, 4, etc., but with different amplitudes; such a series is called a "harmonic series." We thus get a kind of equation for the original curve in a series of arbitrary quantities. We can do just the same thing with a straight line or point, or a profile of a face, or part of a person's signature. From the results we can even reconstruct the original curve. This analysis—called a "Fourrier analysis"—is a perfectly arbitrary one. It does not represent in the least the manner in which the original curve was produced by vibrating bodies or cavities. From a Fourrier analysis we can reconstruct an arbitrary straight line or a signature, but this does not imply that the straight line or a signature was pro-

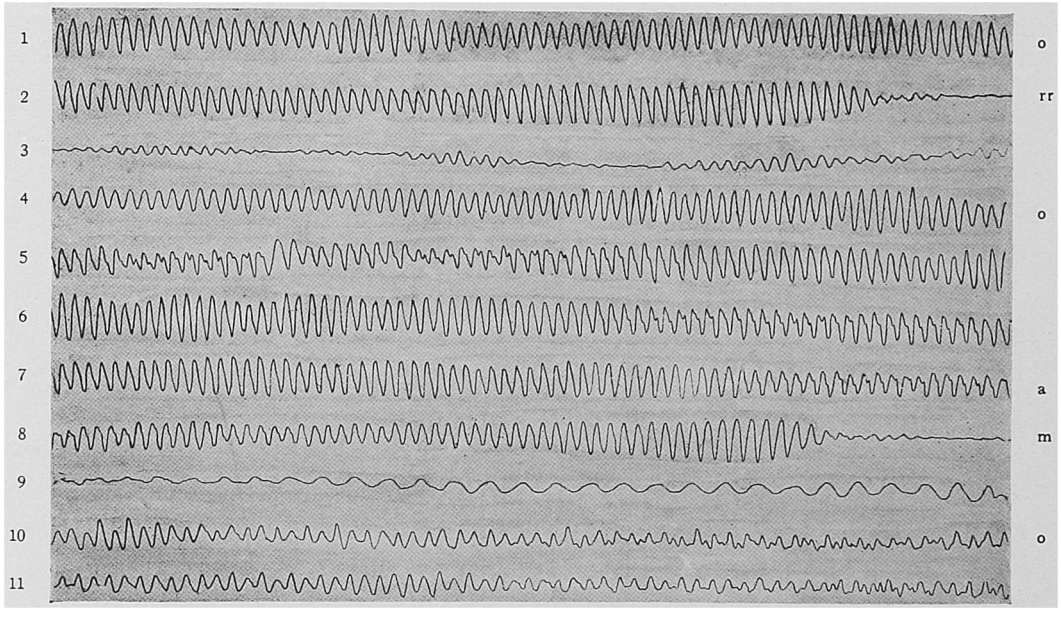


PLATE VII

The first line continues the "o," the second and third lines give the "rr," and the fourth, fifth and sixth lines give the final "o" of "corro." The remaining lines give the "a" and "mo" of "a morir."

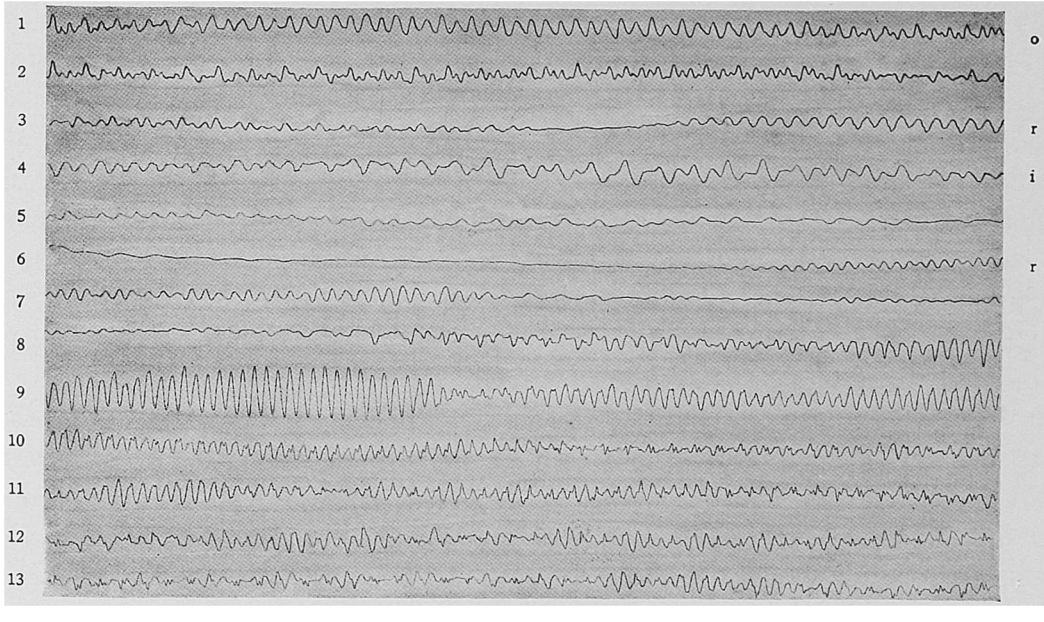


PLATE VIII

This plate concludes the word "morir"

duced by a harmonic series. We can analyze and reconstruct a voice curve in the same way, but it is quite absurd to suppose that this analysis has anything to do with the way in which the voice vibration was accurately produced.

On the other hand, we can analyze a voice curve in quite a different way. We can analyze the voice curve into a series of elements that would conform to the known laws of vibratory masses of muscles like those of the vocal lips and of resonant soft walls like those of the larynx, the floor of the mouth and the cheeks, and with the semi-soft walls like the hard palate. The method involves an immense amount of work for each wave of the voice, but its results are not arbitrary mathematical formulas with no physical meaning, but are definitely established facts concerning the nature of the tone of the voice and the manner in which it is produced.

The results that have been established by these methods prove that the vibration of the voice has not the slightest resemblance to a combination of a series of tuning fork vibrations as was supposed by Helmholtz. Helmholtz's theory served its purpose in stimulating the research work, but has now been abandoned by all the prominent investigators.

An important deduction from the newer work is found in the emphasis to be laid on the proper action of the muscles of the larynx in order to produce a good tone. If the original vibration from the glottis is not good, no amount of modification of the vibration can make it so.